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COMPARISON OF CORN OILS OBTAINED BY EXPELLER AND BENZOL EXTRACTION METHODS.

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INTRODUCTION.

The production of oil from corn germs resulting from the manufacture of hominy, starch, glucose, and sirup has become a well-established industry in the United States. The methods of obtaining the oil from corn germs, also the economic relation of its production to the manufacture of corn products in general, the utilization of the oil, and its future in the vegetable-oil industry of this country have been described in a bulletin of the Department of Agriculture (*43*).[1] Later, a technical study was made of methods for refining corn oil for edible purposes, and a second bulletin was published giving the cost of refining, together with plans and estimated cost for a refinery (*44*).

The present paper deals with still another phase of the corn-oil industry, that of extracting the oil by means of a solvent. With few

[1] The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

exceptions vegetable oils in the United States are at present obtained from the various oleaginous materials by means of pressure. In the case of cottonseed oil the hydraulic press is universally used, while in the production of oil from corn germs the oil expeller has been everywhere adopted. In European countries the extraction of vegetable oils has been to a considerable extent by means of organic solvents, and within the last decade this method has been receiving increasing attention in this country. The success of this method, provided it is found acceptable from an economic standpoint, depends in the case of edible oils largely on whether the oil produced thereby can be freed from the solvent so thoroughly that its flavor will not be affected. This method is finding some application in the production of corn oil and is being considered both for extracting the oil from the germs directly and for extracting the residual oil from the so-called oil cake, or expeller cake.

In the present paper comparison is made of the general characters and quality of three types of corn oil which have been prepared from the same general lot of material so as to make their source comparable. The three types are as follows: (1) Oil produced by expellers at the plant, (2) oil extracted with benzol from germs from the same source, and (3) oil extracted with benzol from the oil cake obtained from the first-mentioned process. These oils were neutralized, bleached, and deodorized, their physical and chemical constants determined, and their color, odor, and taste compared. Such a comparison should show whether there is a possibility of preparing corn oil by benzol extraction that will be equal to that produced by the expeller method.

CHARACTER AND COMPOSITION OF CORN OIL.

Like most vegetable oils which have acquired economic prominence, corn oil has been the subject of much study and investigation. The literature shows that such investigations have been mainly along three distinct lines: (1) Its composition and physical and chemical constants, (2) the methods of its production and its economic relationship to the manufacture of corn products in general, and (3) its uses in the industries. In order to show briefly the extent and character of these investigations, a résumé of the literature is herewith given.

REVIEW OF PREVIOUS INVESTIGATIONS.

The first investigation of corn oil seems to have been published in 1822 by Bizio (*6*), who describes the oil as a reddish yellow liquid with a faint vanilla odor and balsamic taste, one constituent of which resembles stearin. In 1832 Cartis (*8*) called attention to the oil ob-

tained from corn during the distillation of brandy, which he found suitable for lamp oil and as a substitute for linseed oil in paints. The first investigation of the composition of the oil appears to be that reported in 1866 by Hoppe-Seyler (*20*), who found that the saponifiable fat of the corn contains stearin, palmitin, and much olein. Investigations of the oil followed rapidly after this. In 1867 Allemann (*2*) confirmed the presence of palmitic and stearic acids. König (*23*) in 1871 reported that the oil obtained by ether extraction was at first a colorless liquid, but on standing became solid and quite yellow in color, from which he concluded that the oil belonged to the class of drying oils.

The methods of obtaining the oil from corn also began to receive notice. In 1880 Schulz (*41*) described a method of removing the oil from corn mash, and in the next year Leeuw (*24*) suggested the removal of the germ from the remainder of the cracked kernel by flotation in brine of 15° Bé. Maisch (*27*) in 1885 called attention to the fact that corn oil was being used to some extent as a lubricant and for soap making. In the following year (1886) Shuttleworth (*42*) reported on the specific gravity of the oil. In the same year we find the first mention of the oil produced by hydraulic pressure when, according to Wiegand (*53*), Trimble discussed the physical properties of such an oil. Spüller (*48*) in 1887 published the results of a detailed study of the composition of an ether-extracted oil. He reported no free acids and no oxygen absorption in 14 days. A year later Lloyd (*25*), while discussing some of the characteristics of corn oil, reported that as early as 1876 an attempt was made to extract the oil from corn with carbon bisulphid, the purpose being to furnish extracted meal for the distilling industries, but that the venture was abandoned. At the same time Hazura (*13*) reported some work on the iodin number of the oil, and the following year Bowers (*7*) suggested the adaptability of the oil for pharmaceutical preparations, but found that it emitted disagreeable odors on heating, which, he states, would make it unsuitable for frying purposes. In 1889 Kennedy (*21*) and also Heinitsh (*16*) suggested the use of the oil for pharmaceutical preparations. Stellwaag (*49*) in 1890 reported on the constants of corn oils extracted with ether and petroleum ether, respectively. In 1891 De Negri and Fabris (*30*) studied the constants of corn oil, and a year later Smith (*46*) published what appears to be the most detailed investigation of the oil up to that time, his report including its physical and chemical constants, its reaction with alkalis with special reference to soap making, and its application as a lubricant. In 1893 Hart (*12*) and Smetham (*45*) both reported on the constants of the oil. The following year (1894) De Negri and Fabris (*31*) published their second note on the oil and Rokitansky (*38*) isolated linolic acid from it.

From 1894 to 1898 corn oil was subjected to much study, reports on its physical constants being published by Hehner and Mitchell (*15*), Dulière (*9*), and Hehner (*14*). In 1898 Hopkins (*19*) made an extensive study of the oil and Procter (*34*) reported on its physical constants and Wiley and Bigelow (*54*) determined the calories of the oil.

In 1899 Winfield (*55*) published a monograph, including a review of the literature and the results of her study of the oil. At about the same time Archbutt (*3*) reported the oil as semidrying and unsuitable for lubricating purposes. The following year Morpurgo and Götzl (*29*) found that corn oil is difficult to detect in cottonseed oil and in 1901 Vulte and Gibson (*51*) determined the constants of the oil and claimed to have confirmed the presence of hypogæic, arachidic, acetic, and formic acids. In 1903 a comparison of olive oil with corn oil was made by Tolman and Munson (*50*), and Moore (*28*) studied the digestibility of the oil. In the same year Gill and Tufts (*10*) suggested that the presence of sitosterol in corn oil might serve as a means of identifying it when present in other oils. The same authors (*11*) also published during the year their investigation of the unsaponifiable matter. The possibility of corn oil being used as an adulterant in lard was investigated by McPherson and Ruth (*26*) in 1906. Two years later Ritter (*36*) claims to have found the oil equal to olive or cod-liver oil in the treatment of tuberculosis.

In 1909 Wagner (*52*) published an account of the development of the corn-products industry, in which he refers to some of the technical uses of corn oil and Olig and Brust (*32*) reported on the constants of nine samples of corn oil. The refractive index of the oil received the attention of Klimont (*22*) in 1911 and Smith (*47*) in 1912. The following year an editorial (*1*) in the Seifensieder-Zeitung suggested the use of the oil for edible purposes and Pool and Sayre (*33*) studied the oil with a view toward its substitution for olive and cottonseed oils in pharmaceutical preparations. In 1915 the constants were again reported on by Backer (*4*) and Sayre (*39*) found its drying properties to be greatly inferior to linseed oil.

The adaptability of corn oil to cooking and baking and for general edible purposes was pointed out by Sayre (*40*) in 1916. The digestibility of corn oil was found to be similar to that of cottonseed oil and somewhat greater than that of lard by Rockwood and Sivickes (*37*) in 1918, and in the same year Holmes (*17*) found the oil to be digestible and suitable for food purposes. The following year Holt, Courtney, and Fales (*18*) also reported favorably on the digestibility of the oil and its food value. In 1920 Rabak (*35*) studied the effect of mold on the composition of corn oil and reported that the mold apparently feeds on the oil, causing the latter to disappear gradu-

ally and modifying its composition. The most recent work on corn oil is that by Baughman and Jamieson (*5*), 1921, who found the following acids to be present: Oleic, 43.4 per cent; linolic, 39.1 per cent; palmitic, 7.3 per cent; stearic, 3.3 per cent; arachidic, 0.4 per cent; and lignoceric, 0.2 per cent. For purposes of comparison the physical and chemical constants of corn oil as reported by the various investigators are summarized in Table 1.

TABLE 1.—*Physical and chemical constants of corn oil as reported by various investigators.*

Observer.	Physical constants.				Chemical constants.											Remarks.
									Character of fatty acids.							
	Color, odor, and taste.	Specific gravity.	Index of refraction.	Congealing point.	Iodin number.	Acetyl number.	Saponification number.	Free fatty acids.	Insoluble.	Volatile.	Solid.	Liquid.	Melting point or titer.	Iodin number of liquid acids.	Designation.	Unsaponifiable matter.	
				°C.				*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	°C.			*Per cent.*	
Bizio	Bright yellow [1]																
Allemann															Palmitic and stearic.		
Maisch		0.92															
Shuttleworth		.920															
Spüller [2]					119.4–119.9		188.1–189.2	None.	94.7	0.33						1.35	(9)
Lloyd		[4] .916															
Hazura					119.6												
Bowers [5]		.917															
Kennedy		[6] .923															
Stellwaag [7]							{188.5 / 180.5	6.67 / 9.97								3.74 / 3.31	
De Negri and Fabris.		[4] .9218			112.1		190.1						[8]				
Smith	Bright golden [9]	[4] .9244		Turbid at −10; still fluid at −20.	122.9		193.7	.55									
Hart	Dark brown	[4] .9239			117 (Hübl)		189.5	.75	95.7							1.55	
Smetham					116.3		199.3										
De Negri and Fabris.		.9215–.9244		−10 to −20.	111–123		188–193						17 to 20.				
Hehner and Mitchell.					122 (Hübl)												
Dulière		[4] .9243			120.65 (2 hrs.)		198.8–203						[10] 16 to 18.				
Hopkins		.9245 / .9262 / .9258		Fluid at −20; hard at −36.	121.65–123.0					None.					Oleic, linolic, and stearic (?)		(11)
Procter		[4] .9216	[4] 1.4765														

[1] Bright yellow, with greenish fluorescence.
[2] Spüller, J., Chemische Technologie der Fette und Fettöle, Braunschweig, 1882, p. 153.
[3] Lloyd, J. T., Pharm. Rundschau, New York, 1892, p. 10.
[4] Hazura, K., Monatshefte für Chemie, Wien, 1888, p. 1.
[5] Bowers, J. L., Journ. Amer. Chem. Soc., 1892, p. 1.
[6] Kennedy, P. B., Journ. Amer. Chem. Soc., 1892, p. 1.
[7] Stellwaag, F., Chem. Rev. über die Fett- und Harz-Ind., 1894, p. 1.
[8] De Negri and Fabris, Chem. Rev. über die Fett- und Harz-Ind., 1894, p. 1.
[9] Smith, Lewkowitsch, J., Chemical Technology and Analysis of Oils, Fats and Waxes, London, 1895, p. 1.
[10] Hart, E., Journ. Amer. Chem. Soc., 1892, p. 1.
[11] Hehner and Mitchell, Lewkowitsch, J., Chemical Technology and Analysis of Oils, Fats and Waxes, London, 1895, p. 1.
[12] Dulière, W., Chem. Rev. über die Fett- und Harz-Ind., 1894, p. 1.
[13] Hopkins, C. G., Illinois Agr. Exp. Sta. Bul. 31, 1895, p. 1.
[14] Procter, H. R., Journ. Chem. Soc., London, 1895, p. 1.

Archbutt		[6].9243						2.4								1.69	
Winfield		[12].9213	[4]1.4766		118.6	11.49	192.6	1.128	92.23	4.2						1.43	[18]
Morpurgo and Götzl.					147.6	20.58	188.11						18 to 20.				
					124.5	22.75	180.8										
Vulte and Gibson											27.74	72.76		135.97	Hypogæic (arachidic found).		
Tolman and Munson.		[13].9253	[12]1.4768		123.3 (Hübl)		189.9	3.65			7.44		21.6	134.5			
Olig and Brust		.9233–.9272			112.5–128.1		188.7–191.3		92.6–95.3							.6 to .9	
Klimont			1.4745				192.6										
Smith			[1.4675 / 1.4677]														
Backer		[4].922	1.471		110.0 (Wijs)		192.0	.46									
Pool and Sayre				−10 to −15													
Rabak [2]	Pale brownish red.	[14].9204	[14]1.4712		121.0 (Hübl)	15.3	190.3	6.84	93.6	12.8						4.13	
Baughman and Jamieson.[15]		[16].9185	[17]1.4717		117.2 (Hanus).		187.3	1.25							Oleic, linolic, palmitic, stearic, arachidic, lignoceric.	1.7	

[1] Faint vanilla odor, balsamic taste.
[2] Oil extracted with ether.
[3] No oxygen absorption in 14 days.
[4] At 15° C.
[5] Extracted oil.
[6] At 60° F.
[7] First oil extracted with ether; second oil extracted with petroleum ether.
[8] Fusion, 18° to 20° C.; solidification, 13° to 16° C.
[9] Starchy odor, mild taste.
[10] Fusion point.
[11] Oxygen absorption, 4 per cent.
[12] At 15.5° C.
[13] Oil is semidrying.
[14] At 23° C.
[15] The oil was obtained from dry-process germs with an expeller.
[16] At 25° C.
[17] At 20° C.

EXPERIMENTAL WORK.

METHOD OF SELECTING MATERIAL.

In order to make a logical comparison of the oils obtained by both the expeller and the benzol extraction processes it was necessary that both types of oil should be obtained from the same lot of germs. The material used in the experiments was obtained from typical hominy and glucose plants, the former producing dry-process germs and the latter wet-process germs. A day was spent in one plant of each type, and the material was collected, a little at a time, during a period of about seven hours. In this way approximately 150 pounds each of the germs and oil cake and about 5 gallons of expeller oil were obtained. This method of collecting the material gives reasonable assurance that the three types of oil, namely, the expeller oil and the oils extracted with benzol from the germs and from the cake, are derived from approximately the same germ stock. Figure 1 shows graphically the plan according to which the material was collected.

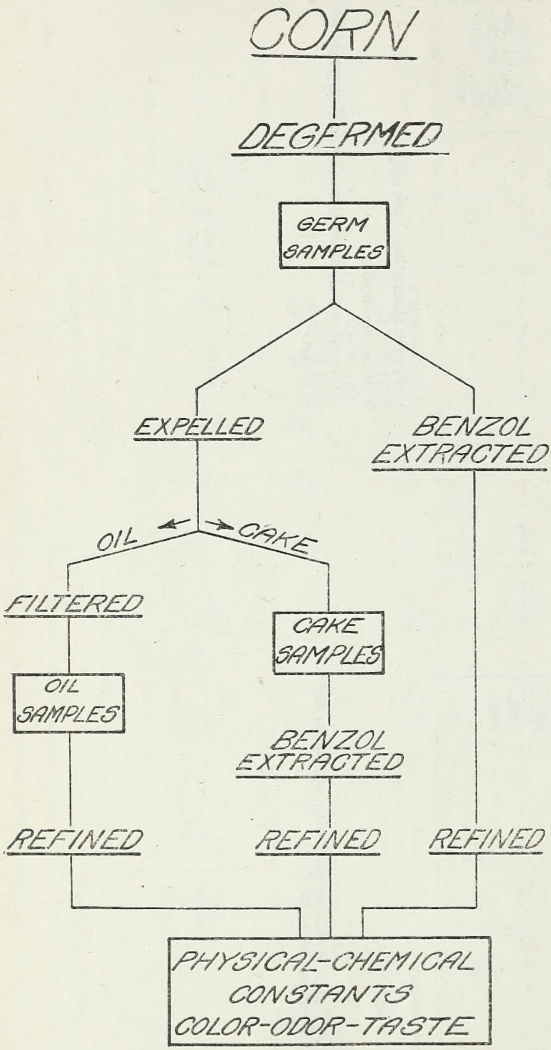

FIG. 1.—Diagram showing the method of collecting corn material for the extraction of oil. This system was used in connection with both dry-process and wet-process germs.

BENZOL EXTRACTION OF CORN GERMS AND OIL CAKE.

The germs and oil cake were ground to a suitable degree of fineness, and 50 pounds at a time were extracted in a large, heavy, gal-

vanized-iron can, in the center of which was a 1-inch glass tube extending below a false bottom. The false bottom consisted of a screen of one-fourth-inch wire covered with several thicknesses of light, coarsely woven cloth. The material was packed on this false bottom and the benzol allowed to percolate through it into the bottom of the can, from which it was removed by means of the tube. The benzol used in all the extractions was a pure so-called water-white grade, which could be distilled completely on a steam bath at a temperature not exceeding 85° C. The first extract was reserved and a new batch of solvent added. The latter was allowed to pass twice through the material and then set aside. A new batch of solvent was added and allowed to pass four times through the material. No further extraction was made, although the material still contained considerable oil, especially the wet-process germs. Table 2 shows the quantity of oil present in the several materials before and after extraction.

TABLE 2.—*Percentage of oil in the wet-process and dry-process germs and in the oil cake before and after extraction with benzol.*

Material.	Percentage of oil present.	
	Before extraction.	After extraction.
Germs:		
Wet process	50.6	7.3
Dry process	23.4	3.1
Oil cake:		
From wet-process germs	13.5	2.8
From dry-process germs	5.2	1.2

The quantity of oil remaining in the material after the extraction with benzol, especially in the wet-process germs, was considerably greater than would be the case in commercial practice.

REMOVAL OF THE SOLVENT.

The last two benzol extracts obtained were mixed, and by heating the extract on a steam bath under partial vacuum approximately 90 per cent of the benzol was removed. The residue of oil, together with the remaining benzol, was then added to the first extract, which contained the bulk of the oil removed from the material. From this mixture the benzol was distilled as thoroughly as possible in the way described. The last portions of the solvent were then removed by passing a current of dry steam into the mixture under reduced pressure. This treatment was continued until no more benzol collected in the receiver. The oil thus obtained still had a very slight benzol odor. If small quantities of water collected in the flask, this was removed from the oil by settling, with subsequent filtration if necessary.

A serious difficulty encountered in the removal of the solvent was the tendency of the oils to foam when the last portions of the benzol were being removed. This foaming was much more severe in the extracts from the dry-process germs, due possibly to the presence of more starchy matter in such material than in the germ stock separated by the wet process, in which all the starch is removed by thorough washing. The presence of the starch also makes the benzol extracts from the wet-process germs exceedingly difficult to filter.

For purposes of convenience the several oils will hereafter be designated as follows: *A*, Wet-process germ by expeller; *B*, wet-process germ by solvent; *C*, wet-process cake by solvent; *D*, dry-process germ by expeller; *E*, dry-process germ by solvent; *F*, dry-process cake by solvent.

APPEARANCE AND CHARACTER OF THE CRUDE OILS.

Samples of the two expeller oils and the four benzol-extracted oils were placed in standard 5¼ inch bottles for the purpose of comparing the color and other characteristics. Some of the oils, especially the benzol-extracted oils from the oil cake, appeared to be somewhat turbid when cold, although they were filtered clear while warm. For this reason the samples were allowed to stand in a dark place for a month and their condition then noted. Table 3 summarizes the appearance of the oils.

TABLE 3.—*Color and appearance of crude corn oils in standard 5¼-inch bottles after standing in the dark for one month.*

Oils.[a]	Color.	Clarity, deposit of solids, etc.
Sample D, dry-process germ by expeller	Bright golden	Very slight whitish deposit.
Sample E, dry-process germ by solvent	do	About ¼-inch whitish deposit.
Sample A, wet-process germ by expeller	Bright golden, with reddish tinge.	Very slight whitish deposit.
Sample B, wet-process germ by solvent	Slightly more reddish than oil A.	About ¼-inch whitish deposit.
Sample F, dry-process oil cake by solvent	Reddish yellow	⅜-inch dark brown deposit.
Sample C, wet-process oil cake by solvent	Reddish brown	½-inch light brown deposit.

[a] The samples of oil are arranged according to their depth of color, lightest to darkest.

It will be noted that the oils from the dry-process material are on the whole somewhat lighter in color than the other oils. However, the same oils also appear to have the heaviest deposits of solids. While, no doubt, some stearin is present in these deposits, yet from the fact that the oils from the dry-process germ material contain the heaviest deposits it may be assumed that a portion of these solids is starchy material. The benzol-extracted oils from the oil cakes deposit by far the greatest quantity of solid matter.

The free fatty acid content of each of the oils was determined, and the results are shown in Table 4.

TABLE 4.—*Percentage of free fatty acids in crude corn oils.*

Oils.	Percentage of free fatty acids.	Oils.	Percentage of free fatty acids.
Sample A, wet-process germs by expeller	1.76	Sample D, dry-process germs by expeller	1.72
Sample B, wet-process germs by solvent	2.15	Sample E, dry-process germs by solvent	1.90
Sample C, wet-process oil cake by solvent	3.60	Sample F, dry-process oil cake by solvent	1.88

It is of interest to note that the oils from the dry-process germs (D, E, and F) are uniformly lower in free fatty acids than the oils from the wet-process germs. There appears to be practically no difference between the free acidity of the benzol-extracted oils and the expeller oil of this group. In the case of the oils from the wet-process germs (A, B, and C), the benzol-extracted oils contain more free fatty acids than the expeller oil. This is especially true of the oil extracted from the oil cake (C).

REFINING[2] THE OILS.

The six foregoing oils were refined as nearly alike as their individual character would permit. The bleaching and deodorizing were done in the same way in the case of each oil, but the method of neutralizing with caustic required some modifications with certain of the oils. It was the intention to treat all as nearly alike as possible, so that whatever differences might be noted in their quality after refining could logically be assumed to be due to the inherent differences in the oils obtained by the two methods of removal from the germ.

NEUTRALIZATION WITH CAUSTIC.

After a number of preliminary experiments it was found that the method of neutralizing the oils with caustic described in a previous publication (*44*) seemed likely to give the most generally satisfactory results on the oils as a whole. After the preliminary experiment, 5-pound batches of oil were used in each case. The method used was as follows:

To the cold oil there was added slowly, while stirring, sufficient 14° Bé. sodium hydroxid to neutralize the free fatty acids present plus 50 per cent excess. After being stirred for 10 minutes the oil was slowly heated while the stirring was continued and the temperature raised to 55° C., until the oil broke. After the break 2 per cent of powdered soda ash was added gradually and the stirring continued for 5 minutes longer. The oil was then kept for 3 hours at a temperature of 50° C., after which it was allowed to cool over night and then drawn off from the deposited soap stock. Channels were cut

[2] The term "refining" as here used includes the three main operations usually employed in making edible oils: (1) Neutralization with caustic, (2) bleaching with fuller's earth, and (3) deodorizing with steam.

in the soap stock and the oil, which drained into these channels upon warming, was removed from time to time until no more could be separated.

All the oils, except F, were treated in the manner described. The time required for the oils to break varied somewhat, oils D and E requiring about 30 minutes to acquire a good break, and oils A, B, and C slightly longer. Oil F presented some difficulty, owing to the presence of mucky, solid matter, and in order to make it break within a reasonable time an additional 50 per cent excess of 14° Bé. sodium hydroxid had to be added. Table 5 shows the refining losses resulting from this treatment.

TABLE 5.—*Refining losses and condition of the soap stock resulting from the neutralization of corn oils.*

Oils.	Refining loss (per cent).		Character of soap stock.
	After first draining.	After final draining.	
Sample A, wet-process germs by expeller.	9.58	5.65	Sufficiently firm to permit channeling.
Sample B, wet-process germs by solvent.	8.27	6.58	Do.
Sample C, wet-process oil cake by solvent.	14.13	12.71	Slimy; occluded considerable oil which can not be recovered to any extent by channeling.
Sample D, dry-process germs by expeller.	5.08	3.69	Same as oil A.
Sample E, dry-process germs by solvent.	6.84	6.49	More slimy than oil D.
Sample F, dry-process oil cake by solvent.	15.0	15.0	Very slimy; no oil can be removed by channeling.

It is found that in the case of both wet-process and dry-process germs the neutralization of the benzol-extracted oil results in a higher refining loss than with expeller oil and that this greater loss is not accounted for by any corresponding difference in the free fatty acid content. In the case of benzol-extracted oils not so much oil can be recovered by channeling the soap stock as is the case with expeller oils. The soap stock from the solvent oils is slimy and occludes more oil than the soap stock from the expeller oils, and this oil can not be recovered to any great extent.

By reference to Table 4 it will be noted that the amount of free fatty acids present will not account for the difference in the refining losses obtained in the oils from wet and dry process germs. Thus solvent oil B from wet-process germs with 2.15 per cent free acids showed about the same refining loss as solvent oil E from dry-process germs which contained only 1.9 per cent of free acids. In the case of the expeller oils from these two types of materials the free fatty-acid content was about the same, yet the oil from the dry-process germs showed a much smaller loss. It is probable that the presence of the substances which cause the foaming of the benzol

extracts of the oils from dry-process germs and retard their filtering are accountable for the greater refining losses in such oils. In the case of the extracted oils from the cake the same condition exists, and a lower refining loss was experienced with oil C than with oil F, although the former contained practically twice as much free fatty acids.

The free fatty-acid contents of the oils after treatment with caustic are given in Table 6.

TABLE 6.—*Quantity of free fatty acids in corn oils after treatment with caustic.*

Oils.	Free fatty acids.	Oils.	Free fatty acids.
	Per cent.		*Per cent.*
Sample A, wet-process germs by expeller.	0.039	Sample D, dry-process germs by expeller.	0.033
Sample B, wet-process germs by solvent.	.050	Sample E, dry-process germs by solvent.	.053
Sample C, wet-process oil cake by solvent.	.058	Sample F, dry-process oil cake by solvent.	.066

It will be noted that after the treatment with caustic the oil contained only a very slight percentage of free fatty acids. The color of all the oils made directly from the germs was quite satisfactory, and oils prepared by benzol extraction did not show to disadvantage as compared with the expeller oils. The oils extracted from the oil cake were, of course, considerably darker than the others, the same general color relationship being evident as that which existed in the crude oils. The color of the oils after the treatment, as read on the Lovibond scale, is included in Table 7 for the purpose of comparison with that from the finished oils.

BLEACHING WITH FULLER'S EARTH.

All the oils were treated exactly alike during the process of bleaching with fuller's earth. The procedure used was as follows:

The oil was heated slowly, with constant stirring, to 110° C., at which temperature it was held for 15 minutes. Then 5 per cent of standard fuller's earth [3] was added and the stirring continued for 10 minutes, at a temperature of 105° to 110° C. The oil was then rapidly filtered on a force filter.

The effect of this treatment on the color of the oils is shown in Table 7 in connection with the discussion of the bleaching effect of the deodorizing treatment.

DEODORIZING.

The deodorizing of the oils was accomplished in half-liter lots in glass flasks by blowing with a current of dry steam at 225° C. (437° F.) for two hours under a vacuum of 25 inches. This treatment had

[3] Standard fuller's earth is recommended by the American Oil-Chemists' Society for bleaching vegetable oils and may be obtained from the secretary of that society.

a noticeable bleaching effect on all the oils. In order to show the relative bleaching effected in the several oils by this and the other processes the color readings are summarized in Table 7.

TABLE 7.—*Color readings of corn oils in standard 5¼-inch bottles with the Lovibond scale after treatment with caustic, bleaching with fuller's earth, and deodorizing.*

Oils.	Color (35 yellow in each case).		
	After treatment with caustic.	After bleaching with fuller's earth.	After deodorizing.
	Red.	*Red.*	*Red.*
Sample A, wet-process germs by expeller	6.6	3.5	3.0
Sample B, wet-process germs by solvent	5.2	4.0	3.5
Sample C, wet-process oil cake by solvent	16.0	10.0	10.2
Sample D, dry-process germs by expeller	4.5	1.6	1.5
Sample E, dry-process germs by solvent	5.8	3.6	2.2
Sample F, dry-process oil cake by solvent	14.0	8.0	5.6

It is of interest to note that the benzol-extracted oils from the germs contained only slightly more red than the expeller oils. On the whole the oils from wet-process germs are darker than those from dry-process germs. The oils extracted from the oil cakes are naturally considerably darker than the others, that from the dry-process cake bleached much more than that from the wet-process cake; in fact, the latter oil is the only one in the entire group in which the color would be likely to interfere to any extent with its use as an edible oil.

COMPARISON OF THE FINISHED OILS.

PHYSICAL AND CHEMICAL CONSTANTS.

In order to show whether the six oils under discussion differed to any extent as regards the usual physical and chemical constants, these constants were determined and the results summarized in Table 8.

TABLE 8.—*Comparison of some physical and chemical constants of the finished corn oils.*

Oils.	Specific gravity.	Index of refraction.	Iodin number (Hanus).	Acid number.	Saponification number.	Acetyl number.	Acids.				
							Insoluble Hehner number.	Liquid.	Solid.	Reichert-Meisel number.	Solidifying point of the mixed acids.
	At 25° C.	*At 25° C.*						*Per ct.*	*Per ct.*		° *C.*
Sample A.	0.9181	1.4723	122.8	0.078	191.7	9.26	95.07	91.27	9.73	0.352	16.6
Sample B.	.9186	1.4726	121.6	.10	189.6	9.81	95.04	91.10	9.90	.312	16.8
Sample C.	.9185	1.4733	123.0	.116	183.0	10.93	92.60	89.96	10.04	.378	16.5
Sample D.	.9177	1.4726	124.8	.066	187.2	7.26	95.06	89.82	10.18	.115	16.0
Sample E.	.9165	1.4732	121.2	.106	194.2	9.99	93.00	89.88	10.12	.190	16.3
Sample F.	.9179	1.4731	125.5	.123	197.5	10.58	92.40	89.61	10.39	.135	16.5

In so far as is indicated by the physical and chemical constants these six oils do not appear to differ to any great extent. Such differences as exist are not any greater than would be expected in several samples of normal oil. Neither do the constants of these oils on the whole show any considerable divergence from those reported by other observers.

QUALITY OF THE OILS.

The only practicable means of judging the quality of an oil which is intended for edible purposes is by its color, odor, and taste. As already stated, all the oils except C, which was extracted with benzol from wet-process oil cake, are sufficiently light in color to make them acceptable for edible purposes. Immediately after the oils were deodorized all samples were carefully tested for general odor and taste. To the writer there appeared to be no perceptible difference between oils A, B, D, and E. The remaining two, C and F, both of which were obtained from oil cake, were quite inferior, and C was the most inferior of the entire lot. In order to obtain a more critical opinion as to the quality of these oils, small samples of each were submitted to two men engaged in practical oil refining and experienced in the judgment of edible oils. The samples were sent two or three weeks after they had been deodorized, which fact should be borne in mind when the findings of these men are considered. Besides the six oils under discussion, a sample of commercial corn oil bought in a grocery store [4] was also submitted, designated as oil X. The entire list was numbered and submitted without any information as to their source or method of preparation except that all were corn oils. One of the judges considered all the oils except C of proper color for edible purposes. As far as odor and taste were concerned he thought he could detect traces of solvent in all the oils except A and B. Since sample B was prepared by benzol extraction and A was an expeller oil, the "off" odor could not have been due to the solvent alone. He considered all but A and B insufficiently deodorized and believed that the peculiar flavor of all but A would make them unsatisfactory for edible purposes.

The opinion of the other man was considerably different. Oil D was considered suitable for salad and B and E good enough for cooking purposes; C was declared to be exceptionally bad, and a peculiar flavor was detected in F and X. While none of the oils were considered "choice," he would rank them as follows, from best to poorest: D, B, E, A, F, X, C. This judgment would place the two solvent oils from the germs between the two expeller oils

[4] This sample of oil was purchased at a store which has a rapid turnover, but the exact age of the sample was not known; hence its quality as compared with the experimental oils must be considered with this fact in mind.

and rank all four of them as better than the solvent oils from the cake.

After these opinions had been received the oils were again tested in the laboratory, and it was found that some deterioration had taken place in some of the oils during the five weeks which had elapsed since they were deodorized. The bottles containing the oils were not quite full and were kept during the interval in a dark place. The changes noted were greatest in the oils from the oil cake and possibly slightly greater in the benzol-extracted oils than in the expeller oils. There seems little doubt that the general quality of these oils could have been materially improved with a more thorough deodorization. The deodorization of oils in the laboratory on a small scale has certain limitations and can not quite compare with commercial operations. The vacuum obtainable in these experiments was not as great as desired, and the arrangement used for raising the oil to the proper temperature might have led to unequal heating. It is probable that a more thorough deodorization would not only improve the quality of these oils but would prevent them from deteriorating rapidly on standing.

SUMMARY.

Corn oils obtained by means of expellers and by benzol extraction from comparable samples of both dry-process and wet-process corn germs and oils obtained by benzol extraction from the expeller cake were compared as to character and quality.

Of the crude oils those extracted from the cake were the darkest and deposited the greatest amount of sediment on standing. The benzol-extracted oils from the wet-process germs contained more free acids than the oils obtained by that method from the dry-process germs, this being especially true of the oils from the cake. All the oils were refined in the same manner, with the exception of the benzol-extracted oil from the dry-process germ cake. Owing to the sediment present, this oil required a greater quantity of caustic. The oils were all deodorized by blowing them with a current of steam at 225° C. (437° F.) for two hours under a vacuum of 25 inches. This treatment removes odorous volatile constituents and in the case of solvent-extracted oils tends to remove the final traces of the solvent.

The expeller oils showed the lowest loss on treatment with caustic; in the oils obtained by benzol extraction from the germs the loss was somewhat greater, and the benzol-extracted oils from the oil cakes showed by far the greatest loss.

There were no striking differences in the physical and chemical constants of the oils either with respect to the two types of germs from which they were produced or to the method of production.

No material difference could be noted in the finished oils from the germs immediately after their preparation, but upon standing some deterioration took place, and this was somewhat more noticeable in the benzol-extracted oils than in the expeller oils.

All the oils except perhaps that obtained by benzol extraction of the cake from wet-process germs were sufficiently light in color to make them suitable for salad and cooking purposes.

The oils obtained by benzol extraction from the two types of oil cake were inferior in all respects to the oils from the germs, that from the cake from wet-process germs being the poorer of the two.

A more thorough deodorization than that to which the oils could be subjected in these experiments might eliminate the remaining traces of either benzol or other odorous constituents, which no doubt account for the slight inferiority noticed in the benzol-extracted oils from the germs.

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